TRANSIT RIDERSHIP AND THE BUILT ENVIRONMENT

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Disclaimer

ABSTRACT

The built environment consists of everything humanly made, arranged, or maintained (Bartuska and Young 1994). In relation to travel behavior, there has been a focus on improving our understanding of how the built environment influences one's travel mode choice. Planners need evidence showing how land use matters as they advocate for the adoption of different planning principles. This is especially true in small urban areas where planners seldom utilize innovative land-use principles, such as smart growth, within their planning process (Peterson 2009).

The objective of this research is to determine what variables (i.e., residential density, land-use mix) play an important role in determining the built environment/transit ridership relationship in the Fargo-Moorhead community. Socio-economic and level of service variables were also considered.

Overall, built environment results indicated that residential density and walkability were significant in predicting transit ridership and performed as anticipated. Land-use mix was also significant, but results were mixed with respect to their influence on transit ridership. Policy makers looking to support land uses that increase both transit use and walkability should consider these implications. Small, medium, and large communities can all benefit from planning techniques that give travelers options rather than car centric neighborhoods that do not provide the needed flexibility to support different transportation modes.

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1. INTRODUCTION

The built environment consists of everything humanly made, arranged, or maintained (Bartuska and Young 1994). In relation to travel behavior, there has been a focus on improving our understanding of how the built environment influences one's travel mode choice. There is mounting evidence that the quality of the built environment influences many key areas of concern to federal, state, and local policy makers, including neighborhood livability and safety, air pollution, traffic congestion, and transit use, among others (Ryan and Frank 2009, Krizek 2003, Ewing and Chen 2003). Planners need evidence showing why land use matters as they advocate for the adoption of different planning principles. This is especially true in small urban areas where planners seldom utilize innovative land use principles, such as smart growth, within their planning process (Peterson 2009).

1.1 Objective

The objective of this research is to determine what variables (i.e., residential density, land-use mix) play an important role in determining the built environment/transit ridership relationship in the Fargo-Moorhead community. Socio-economic and level-of-service variables will also be considered.

1.2 Organization of Content

The study begins with a literature review of travel behavior and health-promoting activities related to the built environment. Following is a discussion of the study area used for this research, highlighting the fixed-route transit system in Fargo-Moorhead. Next is the methodology section explaining the Geographic Information Systems (GIS) development process along with relevant data and their sources. Data analysis then shows results from mean variance and regression estimates. Route-specific analysis is also discussed in this section. Finally, findings and conclusions summarize the research and its applicability for policy makers.

2. LITERATURE REVIEW

Previous research has highlighted the association between the built environment and various human behaviors. For the purpose of this research, travel behavior and health-promoting activities will be discussed. This focus will bring attention to the influence of the built environment on individual travel patterns and healthy lifestyle options.

2.1 Travel Behavior

Travel behavior research focuses largely on mode choice, specifically the decision to drive versus walk, bike, or use public transit. Ewing and Cervero (2001) found that total household vehicular travel is primarily a function of accessibility. This means that densely populated mixed-use developments in the middle of nowhere may offer only limited regional travel benefits. Just because a development is mixed-use in design does not guarantee multiple travel benefits for its inhabitants. Another key finding pertains to trip frequency. They found frequency to be independent of land-use variables, depending instead on household socioeconomic characteristics.

Zhang (2004) studied travel mode choice, finding it is most affected by local land-use patterns. Transit use is primarily dependent on local population densities and secondarily on the degree of land-use mixing. Walking depends as much on the degree of land-use mixing as on local population densities. Therefore, a pedestrian-friendly environment is often different from a transit-friendly environment.

The three D’s: Density, Diversity and Design were studied by Cervero and Kockelman (1997). The authors tested the hypothesis that the “three D’s” affect trip rates and mode choice in the San Francisco Bay Area. Findings showed this to be statistically significant though their influences appeared to be fairly marginal. Compact development was found to have the strongest impact on personal business trips, and while a variable explaining “walking quality” was found only marginally related to mode choice for non-work trips, neighborhoods with traditional street designs and restricted commercial parking were found to average significantly fewer vehicle miles traveled (VMTs) and rely less on single-occupant vehicles for non-work trips. Further, this research showed the relationship between dimensions of the built environment and travel demands were not inconsequential, thus supporting a city planning process that creates more compact, diverse, and pedestrian-oriented neighborhoods which can influence how people live and travel.

The influence of the built environment on travel behavior was also studied by Handy et al. (2005). They found that vehicle miles driven by residents of suburban neighborhoods were 18% higher compared to residents of traditional neighborhoods. Traditional neighborhoods were defined as those built mostly in the pre-World War II era, and suburban neighborhoods were those built more recently. Objective measures of accessibility were also estimated based on the distance along the street network from certain amenities defined as institutional, maintenance, eating-out, and leisure. Changes in the accessibility factor were found to be the most important in explaining changes in driving.

Research specific to transit ridership and the pedestrian environment was conducted by Ryan and Frank (2009). Their hypothesis was that transit trip-making is higher in urban environments that are more conducive to non-motorized travel. This assumes that fixed-route bus systems are most frequently accessed via walking or biking. Built environment data utilized within this research included residential density, retail floor area, intersection density, and land-use mix. Geographic Information Systems (GIS) was used to model the transit network. For example, bus stop stations were depicted as a point in ArcView. The bus stop area was defined as the area within a half mile of the transit stop along the street network.

Ryan and Frank (2009) also used a composite variable that measured walkability of the network system. This "walkability index" used Z-scores to transform the variables to a standard deviation which allowed for variables using different units of analysis. Regression models indicated that the walkability index was significant in determining transit ridership. A major conclusion of this research was the support for transit planning with centrally-located stops within dense, mixed-use activity centers, rather than stops located on the edges of activity centers which had previously occurred to satisfy transit-resistant residents.

A small urban perspective for land-use planning and transit development was studied by Peterson (2009). The objectives of this research were to determine what steps small urban transit providers were taking to integrate transit service into sprawling small urban communities, and to determine what can be done to improve relationships between transit providers and local governments during the land-development planning process. Findings indicated that some transit providers were involved in land-use planning while many had no communication with local city planners at all. Involvement was also found to vary widely from one community to the next.

Peterson (2009) found that the best way to integrate transit within new developments was for transit agency representatives to be present during and throughout the planning process. However, only four of 13 questionnaire respondents indicated they believed sufficient demand existed for fixed-route transit within their new developments. This indicated that even though they may have been involved in planning, new developments are often built at such low densities that implementing new service there would not be feasible. Finally, many agencies responded that even if sufficient demand existed for the implementation of fixed-route service in new developments, finances were not available to extend service beyond its current structure.

Bento et al. (2005) researched travel behavior in a more aggregate form. Metropolitan area data for a number of urban communities was examined to illustrate the effect on commute mode choices and VMT. They found that the probability of driving to work was lower when the population was more centrally located and travel alternatives other than the personal automobile were available. Overall conclusions showed that, for example, moving a sample household from a city with built environment characteristics similar to Atlanta to one with characteristics similar to Boston would reduce annual VMT by 25%.

Safety impact studies have also evaluated the built environment and its influence on travel behaviors. Boarnet et al. (2005) studied California's Safe Routes to School (SR2S) program. Surveys were conducted along with vehicle and pedestrian traffic pattern analysis before and after traffic improvement projects were completed. Changes in perceived safety were measured and changes in the number of children walking and biking to school were also evaluated. Five of the ten traffic improvement projects showed significant evidence of a successful impact. More "walkable" neighborhoods were found to be safer for children and adults alike.

2.2 Health Promoting Activities

Public health researchers have studied the barriers to physical activity due to building codes and structures of the built environment. King et al. (2002) separated human environments into two distinct types, car-oriented and pedestrian-oriented. They characterized car-oriented environments as being built in the last 50 years, having low-density dispersed development, designed with traffic flow as the primary concern, and having limited street connectivity. Pedestrian-oriented environments were characterized as being more compact, designed with public space as the primary concern, and having maximum street connectivity. They also found that pedestrian-oriented environments may be discouraged by government policies, noting lending practices encouraging single-family housing in single-use developments as a prime example.

The Transportation Research Board along with the Institute of Medicine (2005) examined the built environment and its influence on physical activity. They found that environments facilitating more active lifestyles are desirable. The main obstacle to attaining these environments was the costs associated with changing an already-established environment. The research committee also believed that changes to the built environment would be desirable even without the goal of increasing physical activity because of the positive social effects including neighborhood safety, sense of community, and overall quality of life.

Another main conclusion drawn from the Transportation Research Board and Institute of Medicine (2005) study was that research has not yet identified causal relationships that would enable the promotion of targeted changes to the built environment leading to greater physical activity. Effective policies were found to differ for different population groups, different purposes, and in different contexts. Recommendations included the need for an interdisciplinary approach to study all aspects of the built environment by bringing together public health, physical activity, urban planning, and transportation research professionals, among others.

Transit Oriented Development (TOD) and other built environment design techniques have been promoted as a means for achieving active living communities. Lavizzo-Mourey and McGinnis (2003) studied this very issue, finding that something as basic as sidewalks help everyone, from children who need safe routes while walking, to adults who could leave cars at home if they had pathways linking them to local destinations, to older adults who could maintain their independence longer with routine exercise. The research team went on to highlight the increase in obesity rates that is affecting all racial, ethnic, socioeconomic, and age groups. Conclusions found that more Americans would be willing to increase their physical activity if better environmental tools were in place. Also, findings indicated that developers, architects, transportation planners, school board officials, and government leaders must all make physical activity a priority in order to achieve overall success. They admitted that progress in this area has been slow, but the health benefits gained through active living are worth promoting to reduce obesity and inactivity for all populations and age groups.

The collaboration of efforts related to physical activity and land-use planning was the focus of research by Sallis et al. (2004). They found that transportation researchers often study land-use policies and travel behavior while health researchers study recreational physical activities. Expanding models of behavior in both fields may have the potential for more powerful explanatory models for both transportation and physical activity behaviors. Further, these multidisciplinary models may not only improve our ability to explain and predict behavior, but they may lead to more effective changes to enhance health and quality of life.

3. STUDY AREA

The research area for this study includes the Fargo-Moorhead, West Fargo, and Dilworth community served by fixed-route transit. The total population for the three cities was approximately 165,000 in 2010. More detailed demographic data that pertains to transit ridership is shown in Table 3.1.

Table 3.1 Fargo, Moorhead and West Fargo Transit Related Demographic Data

City	Population	White	Minority	No Vehicle Households	Travel Time to Work	Drive Alone to Work	Alternative Travel to Work
Fargo	103,000	92%	8%	7%	14.7 min	84%	6%
Moorhead	35,000	92%	8%	8%	14.4 min	76%	11%
West Fargo	25,000	95%	5%	4%	15.7 min	87%	<2%

U.S. Census (2005)

Census data revealed that between 92% and 95% of the population is white with between 5% and 8% classified as minority. Of households in Fargo and Moorhead, 7% and 8%, respectively, do not own a vehicle while only 4% of households in West Fargo do not own a vehicle. Average travel time to work varied between 14.4 minutes and 15.7 minutes for the three cities, while more than 75% of workers drive alone to work in all three cities as well. Finally, less than 2% of workers residing in West Fargo used an alternative travel method to work while 6% and 11% did so in Fargo and Moorhead, respectively.

Metro Area Transit (MAT) provides fixed-route service six days a week, excluding Sundays, to Fargo, Moorhead, and West Fargo. MAT offers 25 routes that are all wheelchair-accessible with service frequencies ranging from 10 to 60 minutes. Figure 3.1 shows MAT’s fixed-route system within Fargo and West Fargo. Figure 3.2 shows MAT’s Moorhead fixed-route system.

Figure 3.1 MAT's Fargo and West Fargo Fixed Routes

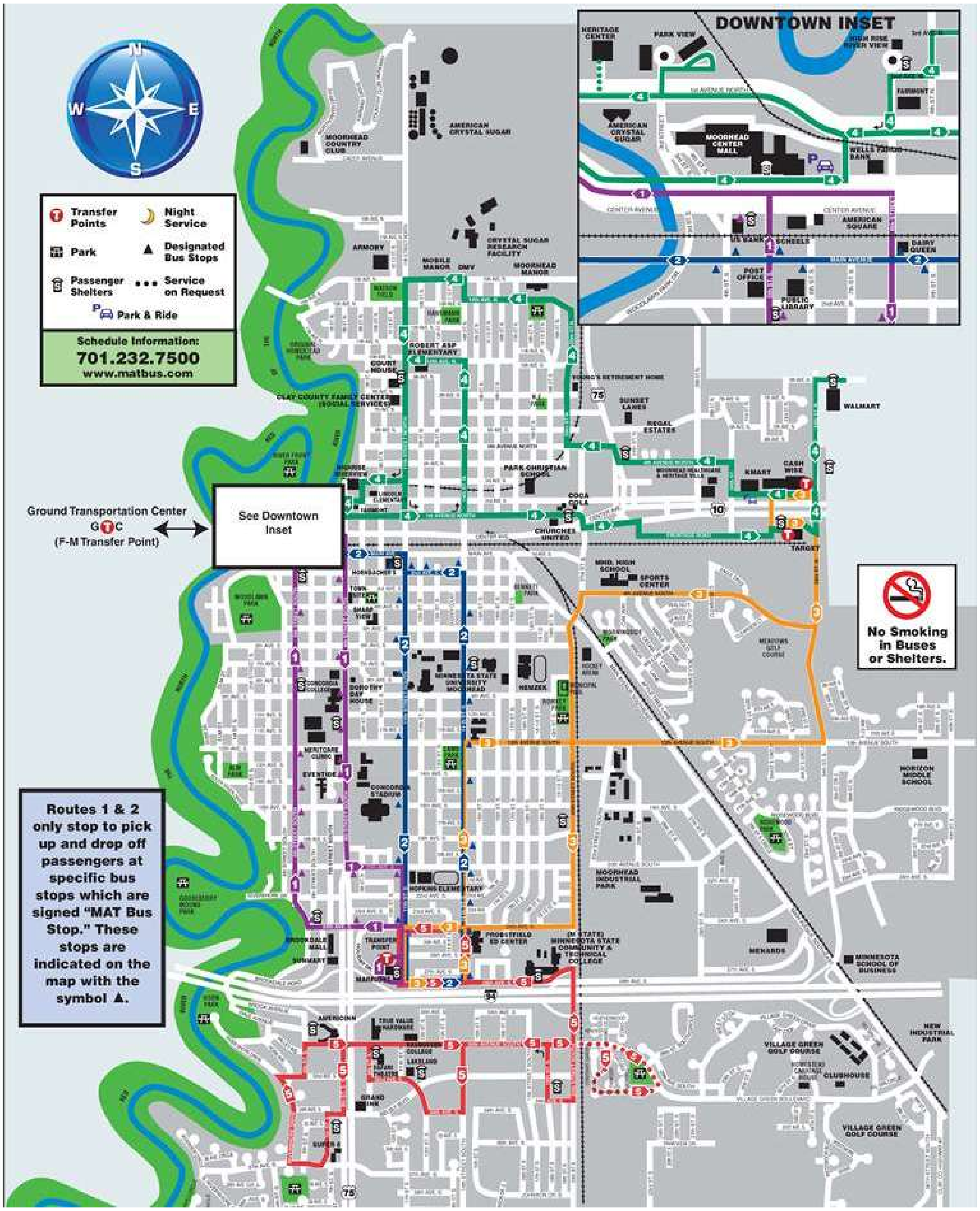

Figure 3.2 MAT's Moorhead Fixed Routes

4. METHODOLOGY

This section highlights the data development process in Geographic Information Systems (GIS) along with other relevant data sources. Ridership data was obtained from MAT while socioeconomic and other demographic data was developed from U.S. Census data. Built environment data was developed within ArcMap 10 following methodology similar to that used by Ryan and Frank, 2009. Table 4.1 shows the different data variables along with their descriptions and data sources.

Table 4.1 Variables, Descriptions and Sources

Variable	Description	Sources
Bus Ridership (2010)	Weekly number of passengers boarding buses on a particular route	Metro Area Transit
Level of Service	Wait time between buses on a particular route	Metro Area Transit
Income	Median Household Income	U.S. Census
No-vehicle Households	Number of total households that do not have a vehicle	U.S. Census
Percent Female	Percent of total population that is female	U.S. Census
Percent Minority	Percent of total population that is not white	U.S. Census
Percent Youth	Percent of total population age 17 and younger	U.S. Census
Percent Elderly	Percent of total population age 65 and older	U.S. Census
Percent Renters	Percent of total households that rent	U.S. Census
Housing units per area	Number of housing units per residential acre	U.S. Census, City of Fargo Land-use Shapefile
Intersection Density	Number of intersections per acre	City of Fargo Road Network Shapefile
Land-use Mix	Proportion of eight land-use types within route area	City of Fargo Land-use Shapefile

4.1 Bus Ridership

Ridership data was collected from MAT for calendar year 2010. Weekly passenger boardings were used as the dependent variable for regression analysis as daily boarding data was uneven and weekly data represented the system's ridership trends more accurately. Fifteen routes within the system were used in the analysis. Evening routes and those specific to college campuses were not used as they would have biased the results. The built environment in and around college campuses was not the focus of this study and that environment is not consistent with "traditional transit use" and how it relates to travel patterns. Therefore, only the 15 routes that would be considered traditional transit routes were utilized.

MAT bus routes were represented as a line in ArcGIS. The route buffer area was defined as the area located within a half mile of the route on either side. Data was not available to model every transit stop and the half-mile radius adjacent to a respective stop. Ridership data by route alone was used as the dependent variable in the regression models. Due to this data collection limitation, there may be sampling errors within the dependent variable. Measures taken based on specific stops would provide a more accurate prediction of actual ridership as this would allow for analysis based on specific points along each route and not just based on the route as a whole. All of the built-environment and socio-economic variables were also calculated for the half-mile route buffer area in ArcGIS.

4.2 Level of Service

The wait time between buses on a specific route (headway) was used to define the level of service for the analysis. The 15 routes studied all had wait times of either 30 or 60 minutes. All wait times for each specific route were therefore defined as either 30 or 60 minutes for that route. Level of service was used as an independent variable during regression analysis.

4.3 Socio-Economic Data

Intuitively, households with lower incomes and those without access to a vehicle should rely more upon transit for their travel needs than others. Median household income and households without a vehicle were both used as independent variables. Also, gender (% female), ethnicity (% minority), youth (% 17 and under), elderly (% 65 and older), and homeownership (% renters) were used as independent variables. Related research has shown that all of these variables can impact transit use (Zhang 2004, Ryan and Frank 2009).

4.4 Built Environment Data

This section defines the built environment data calculated within the route buffer area. Three main measurements were calculated including residential density (housing units per area), street network patterns (intersection density), and land use (land-use mix). These three variables were then used to calculate the walkability of the neighborhood within the route buffer area.

Low residential densities have been shown to encourage automobile travel as increased distances between different land uses, which are usually represented by low residential densities, do not allow for alternative modes of travel such as walking or biking (Ewing and Cevero 2001). Therefore, housing units per route buffer area was used as an independent variable in regression models as well as a variable that was used to calculate neighborhood walkability.

Street network patterns can also influence travel patterns. A denser street network can create an environment conducive to walking as seen in downtown areas as opposed to a sparse street network which is often located in suburbs and within new housing developments. Intersection density was defined as intersections per acre within the route buffer area. This variable was used to calculate the neighborhood walkability index.

Diverse land uses in a given area have also been found to encourage alternative travel options (Moudon and Lee 2005). Land-use mix was used in this study and is defined as the proportion of eight land-use types within the route buffer area. The land use types included park, industrial, commercial, institutional, office, mixed use, vacant and residential. Land-use mix (MIX) was calculated using the equation:

$$MIX = \frac{-\sum[Pn * \ln(Pn)]}{\ln(N)}$$

where

N= the number of different land uses in the route buffer area
Pn= the proportion of acres on the n^{th} land use within the route buffer area

This equation was original applied by Cervero (1988) to study travel behavior. The calculations range from 0 to 1. Values closer to 0 represent buffer areas with less land-use mix whereas values closer to 1 represent route buffer areas with more land-use mix. Measuring land-use mix in terms of acreage is not as accurate as measuring the square footage of a specific land-use because the acreage only quantifies the footprint of the land-use in question. Limited data availability did not allow for square foot measurements, so acreage was used. Land-use mix was used as an independent variable within the regression analysis as well as a variable used to calculate neighborhood walkability.

The neighborhood walkability index was calculated using a combination of residential density, intersection density, and land-use mix. This is similar to the walkability index calculated by Ryan and Frank, 2009. However, due to a lack of data availability, the retail floor area ratio was not calculated in this research. Ryan and Frank (2009) calculated retail floor area as a measure of land-use density and used the variable to calculate their walkability index. Retail floor area information was unavailable for all of Moorhead and West Fargo and was lacking for Fargo as well. Therefore, it was not used in these estimates or within the regression analysis. Calculating neighborhood walkability involves transforming input variables into Z-scores, which turns variables into standard deviations. For this research, neighborhood walkability (W) was calculated as:

$$W = 2 \times [Z(\text{Land-use Mix}) + Z(\text{Residential Density}) + Z(\text{Intersection Density})]$$

5. DATA ANALYSIS

A combination of data analysis including mean variance and regression estimations are discussed in this section. Also, route specific analysis is highlighted focusing on the heaviest and lightest ridden routes throughout the MAT system. Table 5.1 shows descriptive statistics for all variables based on route level analysis for the 15 fixed routes considered.

Table 5.1 Descriptive Statistics

Variable	Units	Range	Mean	Std. Dev.
Bus Ridership	Weekly passengers	99-3219	1252	634
Level of Service	Minutes	30-60	40	14
Income	U.S. Dollars	$8,646-$84,145	$35,452	$14,499
No-Vehicle Households	Households	3-508	53	56
Percent Female	Percent	31%-61%	50%	5%
Percent Minority	Percent	1%-78%	7%	8%
Percent Youth	Percent	1%-39%	20%	8%
Percent Elderly	Percent	0%-39%	12%	8%
Percent Renters	Percent	0%-90%	23%	19%
Housing units per area	Housing units/acre	0-12.9	3.7	2.1
Intersection Density	Intersections/acre	0-0.46	0.22	0.11
Land-use Mix	Index	0-1	0.57	0.27
Walkability	Index	-10.06-10.12	0	3.87

5.1 MAT Ridership

2010 MAT ridership data for the 15 routes studied are shown in Figure 5.1. These routes were chosen because they represent "traditional" fixed-route transit and are influenced similarly by the Fargo-Moorhead built environment. Route 15 was the most heavily ridden route with more than 134,000 annual passengers and route 12 was ridden the least with only 19,000 annual passengers. Routes 13 and 15 combined to account for more than 26% of riders for the entire 15 route system in 2010 whereas the 5 routes that saw the least number of passengers accounted for less than 20% of total ridership. The average number of passengers on each route was nearly 63,000 while the standard deviation of annual ridership by route was roughly 29,000.

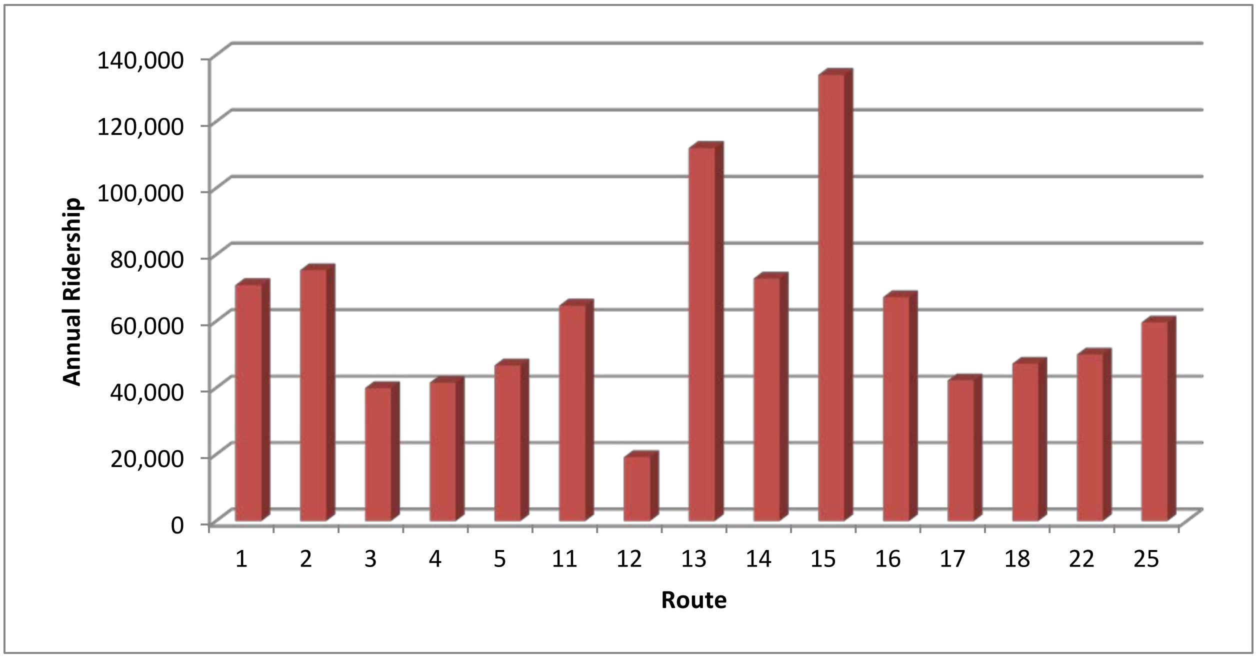

Figure 5.1 2010 MAT Ridership by Route

5.2 Socio-Economic Analysis

The majority of socio-economic data performed as expected during the analysis; however, two variables, median household income and minority percentage, did not. Table 5.2 shows the results for these two variables. Intuitively, bus ridership should be higher among lower-income households. Therefore, median income results were unexpected as the heaviest ridden route, route 15, was only ranked 9th out of the 15 route areas for income. Eight routes had higher median household incomes while 6 had lower median household incomes. Thus, the high ridership on route 15 cannot be attributed to low income levels, but rather to the route structure and its service to a wide range of land-use types. Therefore, there was no obvious relationship between income, minority % and ridership. Also, their effect on ridership may have been overshadowed by other more prominent factors such as level of service along with the built environment variables. This will be discussed in greater detail later in this chapter.

Table 5.2 Income and Minority Results

Route	Ridership	Median Household Income	Income Rank	% Minority	Minority Rank
15	134,011	$34,116	9	6	10
13	112,032	$26,637	14	18	1
2	75,337	$32,319	10	11	2
14	72,807	$37,312	6	7	8
1	70,856	$29,102	13	9	4
16	67,213	$43,007	3	4	14
11	64,673	$31,065	12	5	11
25	59,607	$48,983	1	5	11
22	49,998	$44,319	2	4	14
18	47,223	$31,464	11	8	6
5	46,707	$41,401	4	7	8
17	42,246	$20,990	15	9	4
4	41,539	$34,763	8	10	3
3	39,880	$37,178	7	8	6
12	19,171	$41,000	5	5	11

Route 17 income results were also unexpected. Although this route area ranked last in median household income, it ranked 12th out of 15 route areas in ridership. Thus, the lack of income throughout the route 17 area did not influence ridership significantly. The structure and service area were found to impact the low ridership on this route.

Minority results were also unexpected. Previous literature and research has shown a connection between minority populations and increased transit ridership (Ward and Hill 1996) among others. Based on this assumption, results from routes 15 and 17 were once again unexpected. Although route 15 had by far the heaviest ridership its minority rank was only 10th out of 15 route areas while route 17 ranked 4th in minority population within its route area, but only 12th in ridership. Moorhead routes 4 and 3 displayed similar results with high minority populations within their route area, but low ridership compared to other routes in the system. All of these results showed that route structure and service areas had a greater influence on ridership than either the income levels or ethnicity of the respective residents.

5.3 Built Environment Analysis

Built environment variables and their application with respect to transit ridership in the Fargo-Moorhead area was the impetus for this research. The following discussion summarizes the analysis of three main built environment variables: residential density, land-use mix, and walkability. Table 5.3 shows results for residential density by route area. Results are shown using the variable housing units per acre. These results were quite predictable as higher density areas tend to result in greater transit ridership. This is because if more people live in a certain area there is a larger potential ridership pool to draw from resulting in increased ridership along such route areas. This held true for this research as the heaviest-ridden routes, 15 and 13, were located in the densest housing route areas. Also, some of the lightest-ridden routes, 5, 17, 4 and 3 had the lowest residential densities. The route areas that did not perform as expected were 11, 18 and 12. These route areas had some of the highest residential densities yet had low ridership, respectively.

Table 5.3 Residential Density Results

Route	Ridership	Housing Units/Acre	Density Rank
15	134,011	5.2	1
13	112,032	5.1	2
2	75,337	3.4	9
14	72,807	4.8	4
1	70,856	3.6	7
16	67,213	3.5	8
11	64,673	5.0	3
25	59,607	2.5	12
22	49,998	2.9	10
18	47,223	4.6	5
5	46,707	2.0	15
17	42,246	2.6	11
4	41,539	2.2	14
3	39,880	2.4	13
12	19,171	3.8	6

Table 5.4 illustrates land-use results for this research. These results were mixed with respect to anticipated findings. Intuitively, as land-use mix increases, the likelihood that travelers will choose transit should as well. This is because if different land uses exist within a specific route area (e.g. commercial, residential, institutional, etc.) riders can travel from their homes to other venues for shopping, eating, etc. without walking long distances or transferring to other routes. Therefore, routes 2, 1, and 16 showed anticipated results with high levels of land-use mix and relatively high ridership as well. Routes 18, 17, and 12 also showed predictable results as these routes have relatively low ridership along with low land-use mix levels. Routes 15, 13, 14, and 11 show unanticipated results, however. All of these routes had relatively high ridership, but low levels of land-use mix. The high ridership was found to be primarily because of the main stops they served and not the land-use characteristics within the route area.

Table 5.4 Land-use Results

Route	Ridership	Land-use Mix	Land-use Mix Rank
15	134,011	0.57	8
13	112,032	0.49	11
2	75,337	0.70	3
14	72,807	0.46	12
1	70,856	0.73	2
16	67,213	0.57	8
11	64,673	0.45	13
25	59,607	0.62	6
22	49,998	0.67	5
18	47,223	0.42	14
5	46,707	0.68	4
17	42,246	0.55	10
4	41,539	0.80	1
3	39,880	0.58	7
12	19,171	0.31	15

The walkability of the built environment was also studied with respect to each route area. A combination of residential density, land-use mix, and intersection density, similar to techniques used by Ryan and Frank (2009), was used to quantify the walkability of neighborhoods within specific route areas. The walkability index used Z-score values for residential density, intersection density, and land-use mix in its calculations, yielding an average index of zero among all routes. Thus, any route area with a walkability index of less than zero indicated that route area had relatively lower-than-average walkability while any index greater than zero indicated a route area with better-than-average walkability.

Table 5.5 shows these results. Most of the walkability rankings were anticipated as the highest ridden routes, 15, 13, 2, 14, and 1 all had relatively high walkability indexes. Also, routes with low ridership, routes 5, 17, 3, and 12, showed low walkability indexes as well. The only routes that showed significant unanticipated results were routes 16 and 25 which had relatively average ridership, but low walkability indexes. Route 16 had low intersection densities, which accounted for their low walkability index. Route 25 serves a large portion of south Fargo which has a majority of single-family homes. This resulted in low residential density for that route area and thus, a low walkability index as well. When a variable is dependent on a combination of other variables, such as this walkability index, it can be influenced significantly by one variable that does not perform as anticipated.

Table 5.5 Walkability Results

Route	Ridership	Walkability	Walkability Rank
15	134,011	1.74	2
13	112,032	1.21	5
2	75,337	2.58	1
14	72,807	0.62	7
1	70,856	1.74	2
16	67,213	-1.90	13
11	64,673	1.39	4
25	59,607	-3.06	15
22	49,998	-0.78	9
18	47,223	0.67	6
5	46,707	-1.96	14
17	42,246	-0.85	10
4	41,539	-0.21	8
3	39,880	-1.89	12
12	19,171	-1.32	11

5.4 Route Specific Analysis

This section will look at two routes within the study to provide more in-depth analysis pertaining to route design and its functionality within the built environment. Routes 12 and 15 represent the highest and lowest ridden routes within the MAT system for this research. Each was analyzed to understand what built environment variables have the greatest influence on ridership in the Fargo-Moorhead area.

Table 5.6 shows route 12 and 15 illustrating their ridership and built environment results. Ridership on route 15 was nearly seven times higher than that on route 12. Residential density, represented by Housing Units/Acre, was substantially higher for route 15 compared to route 12 as well. Route 15 ranked first among all 15 routes for residential density while route 12 ranked sixth. The intersection densities for each respective route area were almost identical with 0.20 Intersections/Acre for route 15 and 0.21 Intersections/Acre for route 12. The land-use mix index was nearly twice as high for route 15 (0.57) compared to route 12 (0.31) while the walkability index was substantially higher for route 15 compared to route 12 as well. Overall, route 15 ranked 2nd in walkability among the 15 routes studied and route 12 ranked 11th.

Table 5.6 Routes 12 and 15 Built Environment Data

	Route	
Variable	12	15
Ridership	19,171	134,011
Housing Units/Acre	3.8	5.2
Intersections/Acre	0.20	0.21
Land-use Mix Index	0.31	0.57
Walkability Index	-1.32	1.74

Figures 5.2 and 5.3 illustrate the route design and location for routes 12 and 15 in Fargo. Notice that route 12 runs north/south from downtown Fargo to north Fargo while route 15 runs east/west from downtown Fargo to the West Acres Shopping Center and Wal-Mart in Fargo. Route 12 travels through primarily single family home residential neighborhoods and services the VA Hospital in north Fargo.

The prominence of single-family homes and lack of apartments and townhomes within the route 12 service area lowered the residential density within the route area. Also, little variability in land-use was present within the route 12 service area. Large commercial and/or mixed-use neighborhoods do not exist, reducing the land-use mix of the route area as well. Finally, low residential densities, little land-use mix, and relatively low intersection densities yielded a negative walkability index. All of these characteristics resulted in low and negative built environment measures having a negative impact on ridership.

Route 15, however, illustrates very different built environment characteristics than those of route 12. This route begins on the east side of Fargo downtown serving both residential and commercial areas. Residential densities for route 15 were highest among all routes because the route area includes many apartment complexes and multiple housing unit facilities. Various land-uses were also found within the route service area including residential, commercial, industrial, park land, and office buildings. This led to high land-use mix values relative to other route areas. High residential densities and land-use mix indexes also yielded a positive walkability index. Many riders utilize route 15 to access commercial areas in the western part of Fargo from their residential location in the central and eastern parts of town. This combination of land-uses and residential densities have allowed route 15 to become the most prominent route within the MAT system from a ridership and built environment perspective.

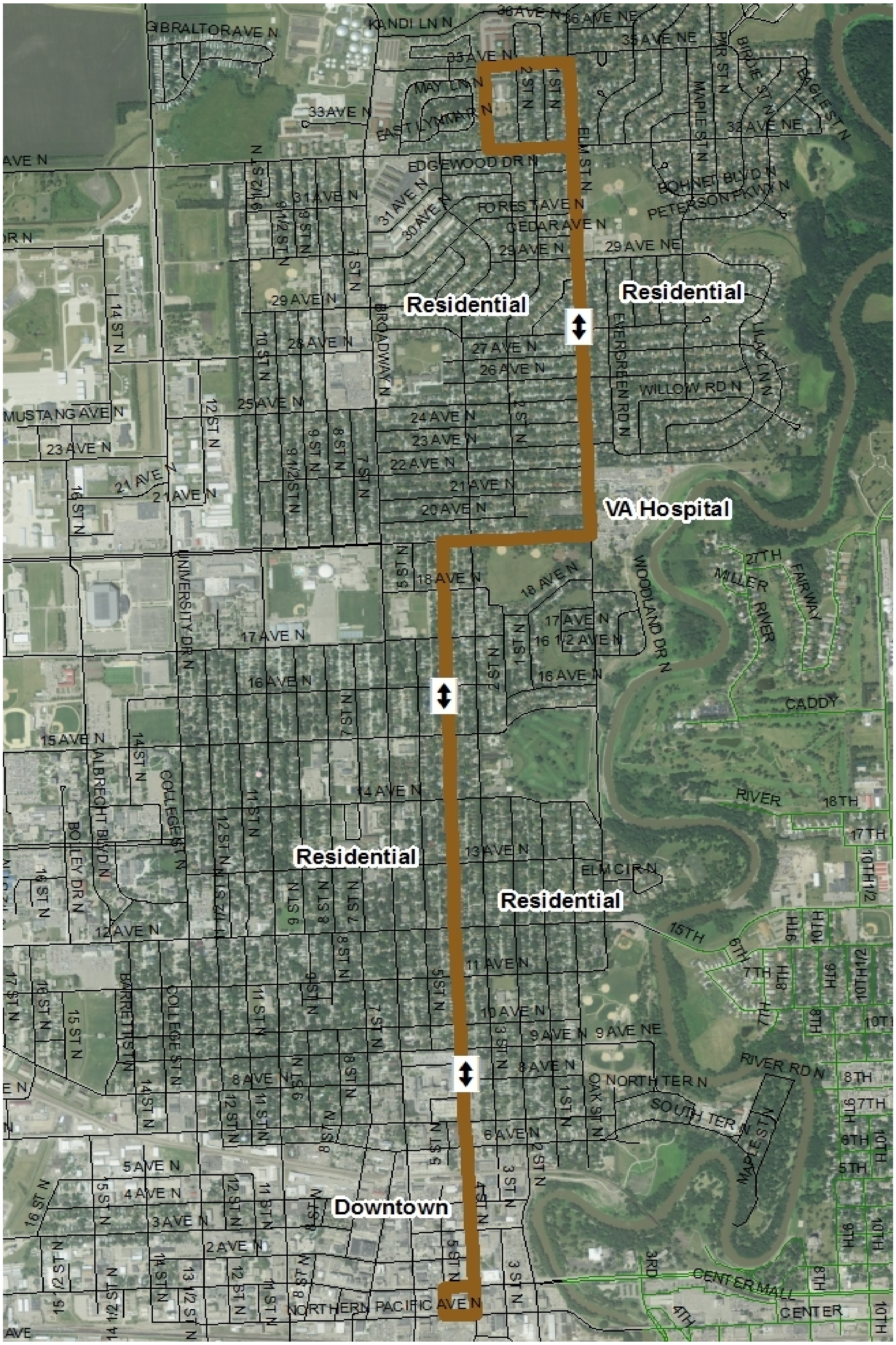

Figure 5.2 Route 12

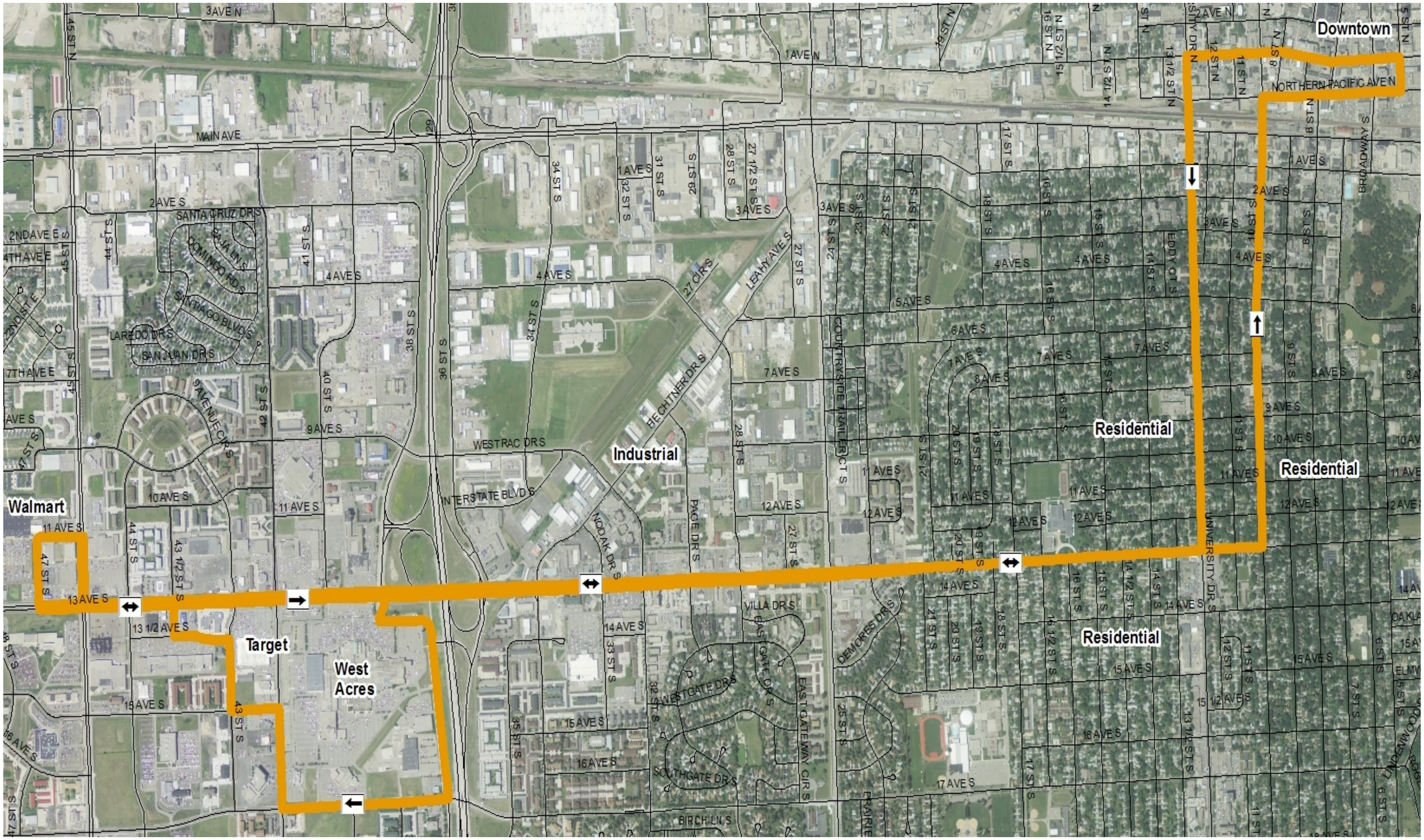

Figure 5.3 Route 15

5.5 Regression Analysis

Regression equations were estimated to determine which variables have a significant impact of transit ridership in Fargo-Moorhead. Regression analysis is a tool that was used to compare factors such as socio-economic status, level of service measures, and built environment calculations. Statistically evaluating such factors using regression analysis provides a more comprehensive, quantitative analysis of the entire transit system. Rather than considering all variables independent of each other as in the previous discussion, regressions illustrate how variables relate and react to one another within the same model. For example, if a significant variable were either added or dropped from a particular regression equation, other variable coefficient values would be changed as a result.

Because all variables (household income, level of service, land-use mix, etc.) should be considered when determining the total effect on transit ridership, regression analysis is an excellent tool that can provide insight into which variables are of significance, and also in determining the magnitude of a specific variable and its influence on ridership. Two separate regressions were estimated. The first included both a residential density variable (housing units/acre) and a land-use variable (land-use mix) as well as socio-economic and level of service variables. The second regression included the walkability index along with socio-economic and level of service variables.

Residential density and land-use measures were not paired with the walkability index in the same regression because they would have biased regression estimates. Housing units/acre and land-use mix variables were used to derive the walkability index, therefore substantial multicollinearity would be present if estimated together. Multicollinearity is defined as a linear functional relationship between two or more independent variables that is so strong that it can significantly affect the estimation of the coefficients of the variables (Studenmund, 2001). The correlation coefficients between these variables were examined and they were found to be highly correlated.

Specifically, the following relationship was estimated:

Transit Ridership = f (Socio-economics, level of service, built environment)

The dependent variable used was weekly transit ridership on the MAT system for the 15 “traditional” fixed routes within the service area. Socio-economic variables included median household income, households without a vehicle, percent female, percent minority, percent youth, percent elderly, and percent renters. The level of service measure used was the wait time between buses on each route. Built environment variables included housing units/acre, land-use mix, and a walkability index with housing units/acre and land-use mix estimated in a separate equation than walkability.

A semilog regression model was utilized to analyze the data set. The semilog model, a variant of the traditional double-log model in which some, but not all of the variables, are expressed in terms of their natural log, resulted in the highest adjusted R-squared values. This measures the goodness of fit for the regression. Coefficient values show how a change in an independent variable (e.g., Households Without a Vehicle) affects the dependent variable (i.e. Transit Ridership). The specific model used to estimate 2010 MAT transit ridership was specified as:

$$\ln \text{Transit Ridership}_{ij} = \beta_0 + \beta_1 \ln \text{Income} + \beta_2 \ln \text{No Vehicle} + \beta_3 \%\ \text{Female} + \beta_4 \%\ \text{Minority} + \beta_5 \%\ \text{Youth}$$

$$+ \beta_6 \%\ \text{Elderly} + \beta_7 \%\ \text{Renters} + \beta_8 \text{Wait Time} + \beta_9 \text{Housing Units/Acre} +$$

$$\beta_{10} \text{Land-use Mix} + \beta_{11} \text{Walkability} + \varepsilon$$

where: Transit Ridership	= 2010 MAT weekly transit ridership
Income	= median household income
No Vehicle	= households without a vehicle
% Female	= percent of total population that is female
% Minority	= percent of total population that is not white
% Youth	= percent of total population that is age 17 and younger
% Elderly	= percent of total population age 65 and older
% Renters	= percent of total households that rent
Wait Time	= wait time between buses on a particular route
Housing Units/Acre	= number of housing units per residential acre within route area
Land-use Mix	= proportion of eight land-use types within route area
Walkability	= walkability index within route area

Table 5.7 shows the estimation results for transit ridership using housing units/acre and land-use mix as built environment variables. All variables were found significant at a 5% level, based on t-tests for individual variable significance. Two socio-economic variables, Income and % Minority, showed opposite signs than anticipated. This was associated with the findings highlighted in Table 5.2. Route 15, the overwhelmingly heaviest-ridden route in the system, did not have a particularly low-income route area. Route 17 had the lowest-income route area compared to others, but was only 12^{th} in ridership compared to the other 15 routes. This discrepancy was thought to result in the positive sign for income. Also, the sign for minority was anticipated to be positive as areas with greater minority populations are traditionally favorable for transit ridership. However, as also highlighted in Table 5.2, the minority population within the route 15 area was lower than average, and the minority population within the route 17 route area was fourth among 15 routes even though ridership was relatively low. This discrepancy was thought to result in a negative sign for minority.

Table 5.7 Estimations for Transit Ridership using Housing Units/Acre and Land-use Mix

Variable	Coefficients	t-stat	Significance
ln Income	0.458	17.291	0.000
ln No Vehicle	0.067	7.751	0.000
% Female	1.260	7.668	0.000
% Minority	-0.688	-6.066	0.000
% Youth	-1.932	-12.957	0.000
% Elderly	-1.989	-20.458	0.000
% Renters	0.558	8.726	0.000
Wait Time	-0.017	-34.227	0.000
Housing Units/Acre	0.011	2.761	0.006
Land-use Mix	0.247	9.793	0.000
Summary Statistics			
Adjusted R-squared	0.261		
F	210		
N	5916		

The level of service variable, Wait Time, was significant and showed the anticipated negative sign. Specifically, the model showed that a one minute increase in Wait Time would lead to a .017% decrease in transit ridership. Finally, both built environment variables were significant and showed anticipated positive signs, although the magnitude of their effect was small. Specifically, estimates indicated that a one unit increase in Housing Units/Acre would increase transit ridership by .011% while a one unit increase in the Land-use Mix index would lead to a .247% increase in transit ridership, holding all other variables constant.

Table 5.8 shows estimation results for transit ridership using walkability as the built environment variable. All variables were once again significant at a 5% level, based on t-tests for individual variable significance. Income and % Minority also showed unanticipated signs as they did in Table 5.7. All other variables showed their anticipated signs while both % Female and % Elderly were of greater prominence in this estimation. Specifically, regression estimates showed that a 1% increase in female population would increase ridership by 1.64%, and a 1% increase in elderly population would decrease ridership by 2.17%.

Table 5.8 Estimations for Transit Ridership using Walkability

	Coefficients	t-stat	Significance
ln Income	0.438	16.695	0.000
ln No Vehicle	0.053	6.267	0.000
% Female	1.642	10.523	0.000
% Minority	-0.549	-5.113	0.000
% Youth	-1.824	-12.370	0.000
% Elderly	-2.165	-22.052	0.000
% Renters	0.561	9.682	0.000
Wait Time	-0.016	-32.928	0.000
Walkability	0.015	8.337	0.000
Summary Statistics			
Adjusted R-squared	0.258		
F	229		
N	5916		

Also, Wait Time was once again significant and negatively related to transit ridership, as anticipated. Finally, Walkability was found to be significant and positively correlated to transit ridership. A one unit increase in the walkability index would cause a .015% increase in transit ridership according to this estimate, holding all other variables constant.

5.6 Summary

A combination of raw data analysis along with route-specific and regression estimations were conducted in this chapter. Both income and minority were analyzed highlighting their source of influence on regression analysis. Built environment variables were studied separately and also included in regression estimates. They were found significant and their influence on ridership was as hypothesized. Two separate regressions were run because the walkability index was derived directly from other built environment variables causing bias in the regression coefficients. The following chapter will discuss findings and conclusions based on methodology and data analysis.

6. FINDINGS AND CONCLUSIONS

The objective of this study was to identify significant variables that play an important role in determining the built environment/transit ridership relationship in the Fargo-Moorhead community. Built environment variables were analyzed along with socio-economic and level of service variables. Fifteen fixed routes were used within the MAT system while routes specific to a certain population (i.e. college students) were not used as they do not accurately represent traditional transit service. A combination of ridership, route specific, and regression analysis were utilized to capture different system attributes.

Overall, built environment results indicated that residential density and walkability were significant in predicting transit ridership and performed as anticipated. Land-use mix was also significant, but results were mixed with respect to their influence on transit ridership. Route specific analysis showed that route 15 was much more beneficial to potential riders than route 12. Route 15 served a wide range of land uses and traveled through both residential and commercial areas connecting downtown Fargo with West Acres shopping center. Route 12 also began downtown, but did not provide riders with high-demand destinations or different land-use types. Regression analysis indicated that all three of the built environment variables were significant in determining transit ridership. Income and minority variables were significant as well, but showed signs that were opposite to those that were anticipated. This was due primarily to the unique aspects of route 15 and its overwhelming ridership accounting for more than 14% of overall ridership.

Results showed that characteristics of the built environment influence transit ridership. Policy makers looking to support land uses that increase both transit use and walkability should consider these implications. Public health and welfare concerns such as air pollution, traffic congestion, and physical activity can all be addressed by investing in walkable, transit friendly environments. Small, medium, and large communities can benefit from planning techniques that give travelers options rather than car centric neighborhoods that do not provide the needed flexibility necessary for different transportation modes.

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